Information carrier, method for producing same

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Technical field

The present invention is generally directed to an information carrier, comprising at least two solid material interfaces, at which information is applied or may be applied by local modulation of at least one solid material characteristic, from which reflection of electromagnetic radiation depends on at said interfaces, and which further comprises at least one intermediate layer between the two solid material interfaces, which layer transmits the said radiation at least to a considerable amount.

As solid material interface we understand the transition area where one material surface is intimately contacted by a second material surface.

The present invention is further generally directed to a method for producing a layer, which at least predominantly consists of Si_xC_y or of $Si_xC_yH_z$ or of Si_vN_w or of $Si_vN_wH_u$ by means of a reactive vacuum coating process, and further is directed to a vacuum coating apparatus which is specifically suited for performing the said method of producing the said layer. The method for producing the said layer is particularly suited for producing at least one layer at the said intermediate layer of the information carrier.

Prior art

In Compact News 1995, "Optical Disc Manufacturing Equipment", so-called high density CDs of different basic principles are

shown in general view.

Therefrom, so-called MMCD or "single sided dual layer high
density CD" or "hdCD" are known as optical information car-
rier in the shape of CDs, at which the information density is
considerably improved. This is achieved by providing two
solid material interfaces, whereat information is stored on a
carrier substrate. The solid material interfaces are separ-
ated by means of an intermediate layer. The information at
the solid material interfaces is applied by local modulation
of a surface pattern of intrusions at one of the material
surfaces forming the interface. Reading information is real-
ized by means of a beam of electromagnetic radiation in the
form of laser light of 635nm or 650nm wavelength or especial-
ly of 450nm. The intermediate layer between the information
carrying solid material interfaces is practically trans-
mittant to 100% at those wavelengths, so that a part of the
impinging beam energy is reflected at the one information
carrying solid material interface and a second part at the
second.

Further, from the article mentioned above, so-called hybrid
MMCD are known, whereat the information provided at respec-
tive ones of two information carrying solid material inter-
faces is selectively read by means of radiation at different
wavelengths, namely, on the one hand, by means of a laser
beam with a wavelength of light of 635nm and, on the other
hand, with a laser beam with a wavelength of light at 785nm.

As was mentioned above, the present invention is most gener-
ically dealing with such information carriers, method for
producing same and apparatus therefor, whereby it must be
pointed out that, under this generic aspect, information at
the said solid material interfaces may be applied by local

modulation of surface structure, as at the well-known optical
storage carriers, or may be provided or applied at in the
sense of magneto-optical storage as is known from the US-5
158 834. Thus, the present invention, under its most generic
aspect, is not limited to information carriers which are al-
ready provided with stored information, as e.g. stored by
mechanical forming process from a master as known from opti-
cal storage disks, but the present invention is also directed
to information carriers which are yet empty of information
and onto which the information is to be loaded or written.

From the article mentioned above, still further techniques
are known for improving information density of CDs. According
to one approach, which is known as SD, "super density", two
substrates each with one information carrying solid material
interface at one side are laid one on the other in back-to-
back relation and are linked. The information is read by
means of a 650nm laser beam from either side of the linked
carriers. By the fact that, according to one improvement of
the SD resulting into so-called "dual layer SD", there is
provided, between the information carrying interfaces, an in-
termediate layer which is transmittant for the light radia-
tion at the wavelength predetermined for reading, the total
information becomes readable from one side of the disk. The
present invention is also directed to an information carrier
of this kind. Thus, information carriers which are the sub-
ject of the present invention, may be generically referred to
as

        "bi- or multiple-reflecting" carriers.

It is common to all such information carriers that electro-
magnetic radiation for writing and/or reading information to
or from the two solid material interfaces is, to a first

part, reflected from a first solid material interface, the
remaining part being transmitted through the intermediate
layer and is reflected as impinging on the second solid
material interface. It is customary that the intermediate
layer comprises at least two layers, one of which being
optically effective, especially contributing to reflection,
the other of which primarily acting as a spacer.

Objects of the invention

The requirement which shall be fulfilled by such an informa-
tion carrier is primarily that information contained at the
said at least two solid material interfaces shall be readable
(or writable) substantially equally. Thus, it is an object of
the present invention to provide an information carrier of
the mentioned type, whereat the said optically effective
layer fulfils at least one of the following requirements:

-   low cost manufacturing;

-   The reflection at one of the intermediate layer surfaces
    and a further material concomitantly forming one of the
    said solid material interfaces shall be as high as
    possible, but simultaneously also transmission through
    the said intermediate layer for radiation of predeter-
    mined wavelength shall be maximized, i.e. absorption
    shall be negligible. Thereby, as a further material, a
    material shall be applicable which is usually used as
    either carrier substrate material or as spacer layer
    material or as covering layer material.

-   The layer shall be applicable at temperatures which are
    so low that known plastic substrate materials may be
    layer-coated.

- In the UV spectral range the layer shall have a high transmission, too, so that, if a UV hardenable lacquer is applied e.g. as an interface co-forming material or as a material of a spacer layer, UV radiation may be applied through the optically effective layer, so as to harden such a lacquer through the optically effective layer.

- The optically effective layer shall further well adhere to common plastic substrate materials as well as to common interface co-forming materials as e.g. to the said lacquer.

- The optically effective layer shall further be suited for applications of radiation in the wavelength band of 400nm to 800nm, but especially for radiation with a wavelength in the band of 633nm to 650nm.

These objects are at least in part achieved by an information carrier which comprises at least two solid material interfaces, at which information is or may be applied and whereat the information is stored by local modulation of at least one solid material characteristic, from which characteristic reflection of electromagnetic radiation depends at said interfaces and which further comprises at least one intermediate layer between the two solid material interfaces, which intermediate layer transmits the radiation and which intermediate layer further comprises a layer which is at least predominantly of Si_xC_y or of Si_vN_w.

Further, at least a part of the objects mentioned above are resolved by an information carrier which comprises at least two solid material interfaces, at which information is or may be applied and whereat the information is stored by local

modulation of at least one solid material characteristic, from which characteristic reflection of electromagnetic radiation depends at said interfaces, and which further comprises at least one intermediate layer between the two solid material interfaces, which layer transmits the radiation, and wherein further the information which is readable from at least one of the solid material interfaces is readable by means of radiation of predetermined wavelength, whereby the intermediate layer comprises a dielectric layer system with at least one layer, wherein the dielectric layer system has an optical thickness D which, at least in a first approximation, is $m \cdot \lambda_o/4$, wherein m is integer and at least unity and is odd and wherein λ_o designates the wavelength of the radiation which is transmitted through the at least one dielectric layer of the dielectric layer system.

Thereby, m may be selected smaller up to 0,6 to its integer value or up to 0,2 larger. Thus, by selecting reduced value of m, and for desired reflection characteristics, a dielectric layer system of significantly reduced thickness may be used, thus significantly improving economic production.

Thereby, preferred dielectric layer materials are Si_xC_y, $Si_xC_yH_z$, Si_vN_w or $Si_vN_wH_u$, but also ZrN or even HfN and TiN may be applicable.

When Si_xC_y, $Si_xC_yH_z$, Si_vN_w or $Si_vN_wH_u$ materials are used as layer material, it has been found that x/y and respectively v/w should be larger than unity, that preferably $x/y \geq 1,2$ and respectively $v/w \geq 1,2$ and, even better, $x/y \geq 2$, respectively $v/w \geq 1,6$.

Thereby, the intermediate layer at the inventive information carrier allows, due to the reflection controlling character-

istics of its material, namely due to refractive index n and
to its transmission characteristics (low absorption), to pro-
vide even more than two, i.e. three or more information
carrying solid material interfaces and to read information
therefrom from one side and preferably with one radiation
wavelength.

It is a further object of the present invention to provide a
method for producing at least one of Si_xC_y and of Si_vN_w and a
method for producing at least one of $Si_xC_yH_z$ and of $Si_vN_wH_u$
layers, which layers thus produced are extremely well suited
for production of the optically effective layer at the infor-
mation carriers mentioned above, but which methods may also
be used for producing layers for different applications. The
inventive methods shall fulfil at least one of the following
objects:

- economic production, especially as concerns complexity
  of plants for performing these methods;

- accurate and relatively simple process control to
  realize desired stochiometry characteristics of the
  layer material;

- realization at relatively low temperatures.

It is obvious that these objects, valid for the inventive
methods, shall also be valid for the apparatus suited for
performing such methods.

At least one of the objects mentioned above is realized by a
method for producing a layer which at least predominantly
consists of at least one, preferably just one of Si_xC_y and of
$Si_vN_wH_u$ by means of a reactive vacuum coating process, which

method comprises the step of freeing silicon from a solid body into the process atmosphere and reacting the freed silicon in the process atmosphere with a reactive gas which contains at least one, preferably just one of C and N.

At least one of the objects mentioned above is further resolved by a method for producing a layer, which at least predominantly consists of at least one, preferably just one of $Si_xC_yH_z$ and of $Si_vN_wH_u$ by means of a reactive vacuum coating process, wherein an optimum of transmission of the layer and of refractive index of the material of the layer is achieved by means of adjusting the concentration of a gas in the process atmosphere, which gas contains at least two of C, N and H, preferably just C and H or N and H.

Preferred embodiments of the inventive information carrier, the method for producing layers and the apparatus for doing so will become apparent to the man skilled in this art when reading the following description of the invention as well as when considering the figures and the claims.

Brief description of the figures

The figures show:

fig. 1   schematically, an inventive intermediate layer at an inventive information carrier under its generic aspect;

fig. 2   schematically, a section of an inventive optical information carrier with two information-carrying solid material interfaces;

fig. 3   in a representation according to fig. 2, a section of

an inventive information carrier with three informa-
tion-carrying, solid material interfaces;

fig. 4   schematically, a first inventive apparatus for pro-
ducing layers and for realizing the inventive methods
for producing such layers;

fig. 5   schematically, a second and preferred embodiment of
an inventive apparatus for realizing either of the
inventive methods and with an inventive target.

In fig. 1 there is shown, principally, a section of a one-
sided, bi- or multiple-reflecting information carrier accord-
ing to the invention. An intermediate layer 3 is embedded be-
tween adjacent materials 2_o and 2_u. The intermediate layer
comprises a dielectric layer 1 and a spacer layer 5. The
latter consists preferably of a lacquer, especially of an
ultra-violet hardenable lacquer as e.g. of a 2P-lacquer of
the firm Philips.

The dielectric layer 1 far preferably consists of at least
one of $Si_xC_yH_z$ and $Si_vN_wH_u$, thereby preferably of one of
these materials, at least to a predominant amount, but can
also at least predominantly consist of Si_xC_y and/or Si_vN_w. It
could be that even materials such as ZrN or HfN or TiN, and
thereby preferably ZrN, may be used as material for the di-
electric layer 1.

Thereby, consisting is to be understood in the sense that
there can be further components in the layer material, but
with a substantially lower amount than the materials just
mentioned above.

The material 2_u and layer 1 form a solid material interface

3_u. The material 2_o and the spacer layer 5 form a second solid material interface 3_o. At these two interfaces an informative structure is applied or may be applied by local modulation of surface characteristics, as e.g. for optical information carriers, of the geometric structure and, for magneto-optical carriers, of the magnetic characteristics.

The informative structure is shown in fig. 1 principally by means of areas 7. The modulated solid body characteristics, i.e. for instance the said geometrical surface structure or magnetic surface structure, modulate impinging electromagnetic radiation 9, as such radiation is shifted along the solid material interfaces 3_o and 3_u, as is perfectly known to the man skilled in this art.

The electromagnetic radiation 9 with an intensity I_o is, on one hand, reflected at the first solid material interface 3_u, according to a reflected part $I_o \cdot R_2$, wherein R_2 is the factor of reflectance. On the other hand, the part $I_o \cdot (1-R_2-A_2) = I_o \cdot T_2$ transits through the layer 3, wherein A_2 is the absorption at the layer and T_2 is the transmission through the layer. This part $I_o \cdot T_2$ transits practically without loss through layer 5 and is reflected according to factor R_1 to become $I_o \cdot R_1 \cdot T_2$. After having passed through layers 5 and 1 again, the radiation becomes $I_1 = I_o \cdot T_2^2 \cdot R_1$. It is to be noted that the transmission T_2 enters as a quadratic term T_2^2 into the expression for I_1.

The energy partitions, as explained and as shown in fig. 1, are approximations which do not take account of the negligible influence of the optically inactive spacer layer 5. With respect to the complicated higher order approximations of these energy considerations, we refer to "Optical Recording", Alan B. Marchant, Addison-Wesley, 1990, Publishing

Company, chapter 13, pages 344-353. The accurate distribution may be calculated with the help of the program "Film*STAR", Optical Thin Film Software, FTG Software Associates, P.O. Box 579, Princeton, N.J. 08542.

Required are two reflected beams 9_{out1} and 9_{out2} which are of an energy which is as equal as possible.

It is known to provide at the intermediate layer 3 a metal or metal-similar layer, as e.g. of Au, whereat, besides of the transmission T_2, the reflection, too, very critically varies as a function of the geometric thickness D_G of the layer and which is expensive in production.

As was mentioned, in a far preferred embodiment of the inventive information carrier, the inventively applied layer 1 consists, at least predominantly, of Si_xC_y, $Si_xC_yH_z$, Si_vN_w or $Si_vN_wH_u$. The layer 1 thereby consists preferably of predominantly one of these materials; nevertheless, at least two of these four materials might be mixed.

The following preferred values and ratios for x, y, z and v, w, u were found:

1.   It is clearly preferred that

1.1 $x \geq y$ and respectively $v \geq w$, irrespective of z and u.

1.1.1   Thereby it is further preferred that

$x \geq 1/2y$ and respectively $v \geq 1/2w$

and even more preferred

$x \geq 2y$ and respectively $v \geq 1,6w$, irrespective of z and u.

This is valid for material of predominantly one of the four mentioned compounds, but would also hold for material composed of two, three or four of these compounds.

Further there is thereby preferred:

2. $x \leq 0,8$, $y \geq 0,05$ and $z \geq 0,1$,

thereby especially

$x \leq 0,52$, $y \geq 0,1$ and $z \geq 0,2$,

$v \leq 0,8$, $w \geq 0,05$, preferably $w \geq 0,1$.

3. The following ratios are considered preferable:

3.1 $[0,445 : 0,262] \leq [x : y] \leq [0,775 : 0,078]$,

irrespective of the value of z and whether a single compound or multiple compound material is provided.

3.2 $[0,445 : 0,249] \leq [x : z] \leq [0,775 : 0,118]$,

irrespective of the value of y and whether a single compound or multiple compound material is provided.

3.3 $[0,078 : 0,249] \leq [y : z] \leq [0,262 : 0,118]$,

irrespective of the value of x and whether a

single compound or multiple compound material is
provided.

3.4   In fact, it has been found that highest index of
refraction of the material $Si_xC_yH_z$ is reached if

$$x:y:z = 0,704 \ (\pm10\%):0,087 \ (\pm10\%):0,131 \ (\pm10\%),$$

is realized, $\pm$ 10% indicating measuring accuracy
and thus statistic dispersion of multiple measure-
ment.

For lowest index of refraction still applicable,
it has been found:

$$x:y:z = 0,494 \ (\pm10\%):0,238 \ (\pm10\%):0,226 \ (\pm10\%).$$

3.5 $$[0,527 : 0,401] \leq [v : w] \leq [0,858 : 0,099],$$

irrespective of the value of u and whether a
single compound or multiple compound material is
provided.

3.6 $$[0,527 : 0,044] \leq [v : u] \leq [0,858 : 0,009],$$

irrespective of the value of w and whether a
single compound or multiple compound material is
provided.

3.7 $$[0,099 : 0,044] \leq [w : u] \leq [0,401 : 0,009],$$

irrespective of the value of v and whether a
single compound or multiple compound material is
provided.

3.8   In fact, it has been found that highest index of
       refraction of the material Si_vN_w is reached if

$$v : w = 0.78 \ (\pm \ 10\%) \ : \ 0.11 \ (\pm \ 10\%),$$

irrespective of u. $\pm$ 10% indicates statistic dis-
persion of multiple measurements.

For lowest index of refraction still applicable,
it has been found:

$$v : w = 0.586 \ (\pm \ 10\%) \ : \ 0.364 \ (\pm \ 10\%),$$

irrespective of u.

This is especially valid if, as electromagnetic radiation 9,
light at a wavelength λ_S is used for which there is valid:

$$400nm \leq \lambda_S \leq 800nm,$$

and wherein there is especially preferably valid:

$$630nm \leq \lambda_S \leq 655nm.$$

In opposition to well-known applications of metallic layers
for realizing the layer 1, the inventively provided layer 1,
especially preferably of Si_xC_y and/or Si_vN_w or even more pre-
ferred of $Si_xC_yH_z$ and/or $Si_vN_wH_u$, makes use of interference,
in that there is valid for the optical thickness D of layer
1:

$$D = m \cdot \lambda_o/4,$$

wherein m is an uneven integer of at least unity, but may be

reduced by an amount of up to 0,6 or increased by an amount of up to 0,2. λ_o is the optical wavelength of the radiation 9 in the intermediate layer material, i.e. especially in the material of layer 1.

Thereby, reflection R_2 becomes significantly less critical with respect to the geometric thickness

$$D_G = \frac{m}{n} \cdot \lambda_o/4$$
(n: index of refraction)

as the optical thickness

$$D = m \cdot \lambda_o/4$$

may vary according to a reduction of m by a value up to 0,6 or an increase of m by a value up to 0,2.

Thus, D_G may be selected considerably smaller (thickness of layer!) than according to integer-valued m, whereby

- reflection is only unsignificantly reduced,
- transmission is significantly increased.

The possibility of providing the layer with reduced thickness (D_G) further significantly increases economic production (increased feed-through).

The fact that generically the reflection is uncritical with respect to D_G further significantly lowers efforts for thickness control in layer production.

As the transmission T_2 appears quadratic at beam 9_{out2} (see fig. 1), increase of T_2 largely improves the energy ratio at

the beam 9_{out1} and 9_{out2} to become equal. As was said, the transmission T_2 appears quadratic in the energy output at beam 9_{out2}. Thus, already a small reduction of geometric thickness leads to a significant improvement at this beam.

Further, the reflection homogenity or distribution along solid material interface 3_0 becomes significantly less dependent on thickness distribution or thickness variations of D_G of the layer 1 on the material 2_u, which is with respect to the production method for depositing layer 1 a significant advantage.

The spacer layer 5, especially for optical information carriers, is preferably formed by a lacquer which may be surface structured, as e.g. by a lacquer "2P" of the firm Philips, i.e. by a lacquer which may be hardened by ultra-violet radiation ($\lambda_s < 400nm$).

The inventive layer 1 has intrinsically a high transmission (low absorption) in the ultra-violet range, which may even be improved by the possibility mentioned above, namely to reduce the geometric thickness D_G of layer 1 without significantly affecting reflection. Thereby, a transmission for ultra-violet range radiation is reached, which is at least 10%. The intermediate layer 3, especially at optical information carriers, is commonly deposited on a plastic material, as material 2_u, especially on surface structured polycarbonate or PMMA.

A significant advantage of the inventive layer 1 may be seen in the fact that the preferred layer materials Si_xC_y and $Si_xC_yH_z$ as well as the said plastic substrate materials and the said lacquer contain carbon, so that rigid adherence of the layer material is achieved with respect to the said

plastic material or lacquer.

So as to realize a reflection R_2 of 30 $\pm$ 10% between common substrate plastic materials, such as polycarbonate or PMMA, and the material of layer 1, a very high index of refraction n_1 is required for the layer material, because the index of refraction of the substrate material is already high: The index of refraction of polycarbonate is e.g. 1.57. If, on the other hand, at the inventively applied material of layer 1 the index of refraction n_1 is increased, this will simultaneously lead to a decrease of transmission T_2, i.e. to an increase of absorption in the material of layer 1. The output signal from solid material interface 3_0, according to fig. 1, is very critically dependent on a decrease of transmission T_2 (increase of absorption). By tailoring stochiometry x/y and especially x/y/z, as was described above, it becomes possible to reach an optimum compromise of the contradictory requirements with respect to index of refraction and to transmission. Especially at the far preferred layer material $Si_xC_yH_z$ it becomes possible by varying two independent parameters, namely carbon content y and hydrogene content z, to optimally set the per se contradictory requirements. A preferred technique to realize such a setting shall be described later in context with the description of the inventive method for producing the layers.

With application of the inventive layer 1 of Si_xC_y, $Si_xC_yH_z$, Si_vN_w or $Si_vN_wH_u$, it became possible to realize reflections R_2 for light at $\lambda_s = 635nm$ at polycarbonate as material 2_u of between 20% and 40%. This led to energy transmitted into the intermediate layer 3 of between 60% and 80%, such energy impinging on the second solid material interface 3_0, taking into account an absorption A_2 at the said wavelength λ_s of practically 0%. Reflection R_1 is optimized by appropriate

selection of the material 2_o according to fig. 1, and was, e.g. using Al as material 2_o, 81% of the energy impinging on the second solid material interface. Thus, and according to fig. 1, for a beam 9_{out1} of 20%, there resulted approximately a beam 9_{out2} of 52%, and for a beam 9_{out1} of 40% there resulted approximately a beam 9_{out2} of 29% of the impinging energy.

With a high degree of probability, the inventive intermediate layer 3 with the inventive layer 1 may also be used for radiation within the blue spectral range, i.e. for light wavelength according to 400nm $\leq \lambda_s \leq$ 500nm. Further, and in the sense of the hybrid MMCD described above, the inventive intermediate layer and layer may be used for applying radiation with selectively different wavelengths, as e.g. of 635nm and 785nm, for selectively reading information at one interface by light of one wavelength, and from the second interface by the light of the second wavelength. Thereby, and with an eye on fig. 1, if e.g. 635nm light is used to read information from interface 3_u and light of 785nm is used to read information from interface 3_o, then the optically effective layer 1 is tailored so that practically all 635nm light is reflected at R_2 and practically all 785nm light is transmitted onto solid material interface 3_o and is reflected there. This is achieved by making the geometric thickness D_G of layer 1 so as to accord with an odd number of quarter wavelengths with respect to the 635nm light, and simultaneously to accord with an even number of quarter wavelengths for the 785nm light.

As was mentioned above for an odd number of quarter wavelengths, m is

$$0,4 \leq m \leq 1,2; \qquad 2,4 \leq m \leq 3,2;$$
(first order)   (third order)

$$4,4 \leq m \leq 5,2;$$
(5th order)

.....

With respect to polycarbonate and most probably with respect
to PMMA on one hand as well as most probably with respect to
the UV-hardenable lacquers, the inventive layer 1 fulfils,
with respect to adherence, the adherence tape tests according
to MIL-M-13508C and/or MIL-C-00675B, as defined in H. Pulker,
"Coatings on Glass", p. 358, Elsevier, 1984.

Fig. 2 shows a preferred embodiment of an inventive optical
information carrier, realized by an optical storage disk with
two information carrying solid material interfaces $3_o'$, $3_u'$.

On a substrate carrier $2_u'$, preferably made of polycarbonate
or PMMA, a layer 1 is deposited according to the preferred
specification under 1) to 3.8).

On the spacer layer 5 there is provided a metallic reflection
layer $2_o'$ made of A_U or Ag, thereby preferably made of Al.
The highly reflective layer $2_o'$ is covered with a covering
layer 2_{oD}.

At a further embodiment shown in fig. 3, the following layers
are provided:

- carrier substrate $2_u'$ preferably made of polycarbonate or
  PMMA;

- layer 1 preferably made of the materials mentioned above,
  namely $Si_xC_yH_z$, Si_xC_y, $Si_vN_wH_u$ or Si_vN_w;

- spacer layer 5 preferably made of ultra-violet hardenable
  lacquer, thereby preferably of a "2P" lacquer which de-

fines the second solid material interface 3_{o1} with re-
spect to a further inventive layer made preferably of
$Si_xC_yH_z$, Si_xC_y, $Si_vN_wH_u$ or Si_vN_w;

- spacer layer 5 preferably made of ultra-violet hardenable
  lacquer which forms the third solid material interface
  3_{o2} with respect to a highly reflective metal, especially
  aluminum layer $2_o'$.

From each of the three solid material interfaces 3_u, 3_{o1},
3_{o2}, there is, preferably again at a laser light wavelength
of 635nm, reflected so much that each of the output beams S_1
to S_3 are of approximately 20% of the impinging energy I. The
absorption of every "semi-transparent" inventive layer 1 is
smaller than 2%, and the respective transmission T_2 is ac-
cordingly high.

The embodiment according to fig. 3 applied to the prede-
scribed MMCD technique results in a storage capacity per one
side of a 120mm CD of approximately 11GByte, whereas e.g. at
a SD (super density disk) there results a storage capacity
per side of approximately 13GByte and for a double-sided SD
of approximately 27GByte.

In the following, the inventive method for producing especi-
ally the described layers 1 shall be described with the help
of inventive reactive layer vacuum deposition apparatus,
which latter may not just exclusively be used for the above
mentioned "semi-transparent" layers 1 at the inventive infor-
mation carrier, but which are especially suited for that ob-
ject.

At the apparatus schematically shown in fig. 4, the "semi-
transparent" layer 1 (figs. 1 to 3) is deposited by means of

ion plating, whereas in a preferred apparatus, according to fig. 5, and in a preferred manner, the inventive layer 1 is deposited by means of reactive sputter coating.

With the inventive methods of producing such layers - other methods appear possible, too -, as one most important aspect, the relation of transmission T_2 and index of refraction n_1 at the preferably deposited $Si_xC_yH_z$ and/or $Si_vN_wH_u$ layer is optimized by controlling the ratio of carbon to hydrogene. This is preferably realized by feeding at least two gases to the process atmosphere, which gases have different C/H or N/H content ratios each. Thereby, the content of these two gases in the process atmosphere may be open-loop controlled or negative feedback controlled. A second alternative or additional aspect is that silicon atoms are freed into the process atmosphere from a highly pure silicon solid body and react in the process atmosphere with carbon-, preferably with carbon- and hydrogene-containing gas. Under the first aspect, i.e. by controlling the amount of the said two gases in the process atmosphere, the optical parameters are optimized. By the second, a most economic and well controllable process is realized.

As a process discharge gas, preferably a noble gas as e.g. Ar, is used.

As reactive gases, carbon hydrogene gases, as e.g. Butane C_4H_{10}, Methane CH_4, Propane C_3H_8, Nitrogen N_2 or Nitrogen-hydrogen gases may be used, whereby, by open-loop or negative feedback loop controlling each gas flow to the process atmosphere, more or less carbon C or nitrogen N is introduced per time unit compared with hydrogene fed to the process chamber per time unit.

The silicon, freed from the silicon solid body source, allows use of low price solid body sources compared, e.g., with the case where SiC is freed from well-known graphite-doped silicon sources. By means of accurately predetermining the composition of the silicon of the solid body source, the overall layer deposition process becomes more controllable and, by varying process gas composition, adjustable.

According to fig. 4, which shows schematically an ion plating apparatus, a plasma discharge PL in a vacuum chamber 51, between electrodes 53 and 54, is maintained. By means of the discharge PL, silicon of a target 55, as shown at the electrode 54, is evaporated or sputtered into the process atmosphere. Instead (not shown) of a plasma discharge PL, there may also be used, and as known to the skilled expert, thermic evaporation of silicon, as e.g. by means of electron beam.

The plasma discharge PL may be operated either with Rf-voltage or with DC or with DC and superimposed Rf or with DC with superimposed medium frequency Mf-energy or with DC with superimposed low frequency Lf-signal, whereby, preferably, DC is used with superimposed Mf or Lf pulsating voltage.

It must be considered that the layer material produced in the process atmosphere as well as silicon per se are poorly electrically conducting, so that, with an eye on arcing and source poisoning by isolating layers, much care must be taken for appropriate process control.

In a far preferred embodiment as shown, the plasma discharge PL is operated by means of a DC source 57. Stability of the coating process is maintained in spite of the use of a low cost DC source 57, by superimposing to the output signal of the DC source $U_=$, an AC voltage with a frequency in the me-

dium or low frequency range, which is preferably a pulsating
voltage. As schematically shown, this AC voltage is prefer-
ably intermittently superimposed at a superposition unit 58
to the output DC signal of source 57. Such signal superposi-
tion is preferably realized by interconnecting the two dis-
charge electrodes 53 and 54 intermittently by means of the
chopper unit 59, which intermittently interconnects these
electrodes alternatively high ohmically and low ohmically.
This preferred technique is shown in broken lines. Either a
predetermined fixed chopper repetition rate and/or duty cycle
is used or, and preferably, the occurrence of disturbance
arcing is automatically monitored in the process recipient
and controls via chopper unit 59 low ohmic connection of the
two discharge electrodes 53 and 54, thereby preventing
arcing.

This superposition technique is described completely and in
detail in the European application no. 0 564 789 which ac-
cords with the U.S. application no. 08/020 672 or 08/300 865
and to the Japanese application no. 5-65052.

With respect to this preferably used choppering technique,
the said patents and applications shall be considered as in-
tegrated part of the present description; the U.S. applica-
tion 08/300 865 is enclosed to this specification as an
appendix A.

In the vacuum chamber 51, there is further provided a work-
piece carrier electrode 60, which, e.g. with respect to elec-
trode 54, is fed with a negative DC electric potential by
means of a DC source 62. Here, too, a superposition unit, as
was described, realized preferably by means of a chopper unit
64, according to the predescribed chopper unit 59, allows to
maintain stability of the layer deposition process at the

workpiece carrier electrode 60. With respect to electric
potential, which is applied to the housing of the chamber,
the electrodes 53, 54 and 60, the skilled expert knows dif-
ferent possibilities, also with respect to defining and
applying reference, i.e. ground potential.

Inventively, a gas tank arrangement 66 is provided, from
which a reactive gas G containing carbon C and/or nitrogen N_2
and preferably further hydrogene H is fed to the chamber 51,
i.e. into the process atmosphere. This besides a plasma dis-
charge working gas, which is normally selected to be Ar. Pre-
ferably, the gas G results from controlled mixing of two
gases G_1 and G_2, as schematically shown, by means of control-
lable valves V_1 and V_2. If the two gases, as e.g. Propane and
Butane or Nitrogen and Ammonia, have different stochiometric
ratios (e.g. Butane 2/5; Propane 2/7), the control of varying
contents of the gases G_1/G_2 in the process atmosphere con-
trols the ratio of C/H or respectively of N/H in that atmos-
phere, and thus at the $Si_xC_yH_z$ or $Si_vN_wH_u$ layer which is
growing. Thus, by means of two independent parameters, namely
the C and H or N and H content, the transmission T_2 and the
index of refraction n_1 at the growing $Si_xC_yH_z$ or $Si_vN_wH_u$
layer is controlled.

If only one gas is used as a reactive gas, preferably Propane
is used for $Si_xC_yH_z$ and Nitrogen for Si_vN_w.

Today, layer deposition is preferably realized by magnetron
sputtering. Fig. 5 schematically shows, as an example, an
apparatus for such magnetron sputtering. From the magnetron
source 70, silicon is freed into the process atmosphere of
the vacuum recipient 71. The magnetron electrode 70 is con-
nected to a workpiece carrier electrode 73 via a DC source
75, as was described, whereby, again, a chopper arrangement

77 of the kind which was mentioned above is used (shown in dashed lines). This is a preferred realization of super-imposing an AC voltage to the output DC voltage of the DC source 75 at the superposition unit 78. Thereby, again, the AC voltage is preferably selected as a medium frequency or low frequency signal, and is preferably pulsating.

In the operating mode with a DC-driven plasma discharge PL at ion plating according to fig. 4 and especially for DC oper-ated sputtering according to fig. 5, an inventive silicon target is preferably used, which is negatively or positively doped, preferably with Boron and/or Phosphor. Thereby, pre-ferably the specific resistance of the target material made of doped silicon, ρ_{Si}, is:

$$0,01\Omega cm \leq \rho_{Si} \leq 6\Omega cm.$$

Thereby, in a preferred mode, the following is valid:

$$0,4\Omega cm \leq \rho_{Si} \leq 0,6\Omega cm.$$

By this it is achieved that the per se low conductive silicon has an increased conductance ρ_{Si}^{-1} and may be even DC sput-tered or, as was explained, preferably sputtered by means of a DC voltage with superimposed AC component. Thereby, as we described, parallel chopper technique is preferably used.

This mode of operation allows a most economic operation at a high deposition rate, whereby the silicon allows further to reach a high layer quality due to the fact that it is sput-tered without arcing and without occurrence of droplet.

The reactive gas G is applied as a single gas or as a gas mixture, as was explained with respect to fig. 4. The layers

may be deposited with a magnetron source 70, as known per se, so e.g. by placing the carrier substrates just in front of the target. The carrier substrate may also be moved along the target, so e.g. in linear in-line coaters, or may be rotated passing the target, as e.g. in plants with rotating cylindrical workpiece carriers.

Before results are presented, the advantages of the inventive information carriers and of the inventive method of producing layers and thus of apparatus suited to perform such methods shall be listed in summarized form:

With respect to the information carrier with inventive intermediate layer:

- At a selected wavelength (preferably 635nm) of the electromagnetic radiation for applying and especially for reading information from the solid material interfaces, between which at least one inventive intermediate layer with layer 1 is situated, a high transmission T_2 of the intermediate layer is reached, and a high reflection at a surface of the intermediate layer (figs. 1 to 3).

- The transmission T_2 of the inventively provided layer 1 is high for ultra-violet light ($\geq 10\%$), so that lacquers, which are applied and which are ultra-violet hardenable, may be hardened by ultra-violet radiation transmitted through the layer 1 with a high effectiveness.

- Adherence of the layer 1 with respect to covering materials which comprise C, as especially with respect to plastic materials, thereby especially to polycarbonate or PMMA, and with respect to the ultra-violet hardenable lacquers as mentioned is high, because the material of

the inventive layer also comprises the element C.

- By deposition of the layer 1 with an optical thickness, which substantially accords with an uneven number of quarter wavelength with respect to the wavelength of the radiation considered, the reflection becomes less critical with respect to the exact geometric thickness of the intermediate layer, and additionally it becomes possible to increase transmission of that layer by depositing layer 1 with reduced thickness (m -0.6) than is defined by the uneven integer number m of $\lambda_o/4$ optical thickness.

- Especially with using $Si_xC_yH_z$ or $Si_vN_wH_u$ layer material for layer 1, i.e. with C and H or with N and H, two independent parameters for tailoring transmission and reflection of the layer 1 and the intermediate layer respectively are exploitable.

- The inventive intermediate layer with the layer 1 opens the possibility of economic, easily controllable manufacturing processes and of their realization by means of low cost apparatus.

With respect to the method of producing layers:

- The use especially of doped silicon targets is economic and simple, the according targets are easily manufacturable.

- By applying gases which contain carbon, hydrogen or Nitrogen, relatively low cost and safe gases are used.

- By the use of a DC coating technique with the AC superposition which was described, expensive high power AC

generators become obsolete. Arcing and other process instabilities are nevertheless accurately avoided, although low cost and technically simple generators are used.

1. Example:

An $Si_xC_yH_z$ layer was deposited on a polycarbonate substrate. Thereby, an apparatus was used as principally shown in fig. 5. The substrates were deposited on a cylindric carrier and were rotated passing a rectangular magnetron source. Thereby, the minimum distance between substrates and target surface was 70mm.

Target material: Si(99,99%), p-doped with Boron, $\rho_{Si} = 0,5\Omega cm$;

Discharge current feed: 10kW/DC with chopper unit according to 77 of fig. 5;

Discharge operating gas: Ar;

Reactive gas: Propane, C_3H_8;

Reactive mode / metallic mode: Negative feedback control by monitoring the deposition process with the help of a plasma emission monitor and adjusting chopper unit 77 as well as the flow of Argon and Propane by means of adjustable controllers according to V_1/V_2 of fig. 4;

Discharge power: 7kW;

Rotational frequency of
workpiece carrier 73:   0,5Hz.

In the following table, three batches no. 2, 3 and 4 are
specified with respect to coating process parameters.

Batch	Power kW	Argon flow sccm	Gas pressure ϵ-3mbar	Metallic mode voltage UMM V	Reactive mode voltage URM V	Propane flow qC_3H_8 sccm	Flow ratio qC_3H_8:qAR	Sputtering time s
2	7	25.5	4	807	777-780	5.9	23.14%	377
3	7	25.5	4	800	724	12	47.06%	377
4	7	25.5	4	828	765	11.4	44.71%	225

At the batches no. 2, 3 and 4, the following values were
measured:

Batch	Index of refraction at 635nm n	Extinction coefficient k at 635nm k	Reflection at 635nm %
2	3.19	1.47	38
3	2.28	0.35	13
4	2.59	0.67	23

By the inventive $Si_xC_yH_z$ coatings applied to polycarbonate
substrates, at batch no. 4 a reflection of 40% was measured
at a wavelength of 635nm and from the layer-to-air-side. The
amount of transmitted light through the polycarbonate carrier
substrate with a thickness of 1.2mm and with the inventive
layer thereon was 60% at the wavelength of 635nm, which
accords with the transmission T_2 of practically a 100%, i.e.
to an absorption of practically 0%, which is thus neglect-
able. The amount of transmitted energy at a wavelength of
360nm was still 12%. At the batches no. 2 to 4, as specified
above, the following stochiometry was achieved:

Batch No.	Si	:	C	:	H	:	O
no. 2	0.529	:	0.116	:	0.295	:	0.06
no. 3	0.401	:	0.227	:	0.29	:	0.082
no. 4	0.42	:	0.203	:	0.33	:	0.047

There resulted, with an eye on fig. 1,

$$0{,}2 \leq R_2 \leq 0{,}4 \text{ and}$$

$$0{,}2 \leq (R_1 \cdot T_2{}^2) \leq 0{,}4.$$

As band for the index of refraction, we first propose: $2{,}59 \leq n_1 \leq 3{,}2$ for polycarbonate substrate material.

For the index of refraction k, we first propose the following values:

$$k_{300nm} \leq 1{,}5 \text{ and}$$

and/or $\qquad k_{600-700nm} \leq 0{,}5,$

especially $k_{600-700nm} \leq 0{,}1,$

and/or $\qquad k_{450-500nm} \leq 1.$

By the realization of an information carrier structure according to fig. 3 with the deposition processes as disclosed above, the beams S_1 to S_3 had about 20% of impinging energy at an absorption of 2% at most for light at the wavelength of $\lambda_s = 635nm$.

2. Example:

As a result of the first example mentioned above, we noted

that with stoichiometric or nearly stoichiometric semitrans-
parent layers made of SiC, we reached index of refraction n_1,
not really exceeding the value of 3.2 at a wavelength of
633nm. On the other hand, it first seemed impossible to use a
more accentuated unstoichiometry and thus higher index of
refraction because of the large k-value which were supposed
to occur. It further seemed impossible to reach a signal spex
of 25% for the blue laser at 450nm wavelength.

Nevertheless, the inventors went on with further experiments
that showed that higher index materials would allow to use
thinner layers, so that, even with increased k-value materi-
als, the transparency decrease would not be detrimental.
Thus, and as will be shown in this example, index of refrac-
tion well above 4, up to 4.6 and specifically at 4.2, were
reached with k-values $k_{350nm} \leq 2.5$, $k_{600-700nm} \leq 0.5$ and
$k_{450-500nm} \leq 1$.

Using Si as target material, high index of refraction layers
were realized by reactive sputtering in nitrogen instead of
hydrogenic carbon gas according to example 1. Even experi-
menting on a more stoichiometric version of $Si_xC_yH_z$ showed
that it is possible to reach, even at 450nm, 25% signals from
both information layers.

$Si_xC_yH_z$, Si_xC_y, $Si_vN_wH_u$ and Si_vN_w layers were deposited on
polycarbonate substrates. Although an apparatus as shown in
fig. 5 could be used, an SDS 100 apparatus of Balzers was
used where the substrate is kept stationarily with respect to
the target.

Substrate-to-target distance: 40mm

Approximate reaction volume: 5000cm^3

Target material: as in example 1.

Discharge current fee: as in example 1.

Discharge operating gas: as in example 1.

Reactive gases: Methane for Si_xC_y and $Si_xC_yH_z$.

Nitrogen and ammonia for: Si_vN_w and $Si_vN_wH_u$.

Discharge power: 4kW.

In the following table, four typical batches with highest index of refraction reached and lowest index of refraction reached and still applicable are specified with respect to coating parameters, indicating the preferred range for digital-video disk coatings made of silicon carbides or silicon nitrides.

Table 1: Process parameters and resulting n and k values

batch	layer	flow N2	flow CH4	flow Ar	voltage V	n633nm	k633nm	k350nm	n450	k450
6	Si_vN_w	.4	0	32	540	4.19	.5	2.43		
12	Si_vN_w	14	0	32	542	3.02	.18	1.01		
42	SixCy	0	4	32	557	3.97	.24	2.33	4.35	1
45	SixCy	0	16	32	555	2.81	.03	0.95	3.04	0.33

Table 2 shows measured and calculated results, the reflectance R and the transmittance T measurements were done by a Lambda-9 spectral photometer of Perkin Elmer on corning test

substrates. From the R-T measurements, n and k values have been calculated. From the n and k values, the optimal thickness for highest possible signals S_1 and S_2 from both information carrying interfaces valid within the stack were calculated using the Film Star Program mentioned above. The optimal index giving the highest possible signals lies for SiC between n = 3,97 and n = 2,81. At n = 3,13 and k = 0,06 one gets signals of S_1 = S_2 = 32,2%, i.e. only 2,4% below the theoretical limit when Al is used as high reflecting back layer.

Table 3 shows the corresponding stoichiometry to the postulated limiting index of refractions useful for digital-video disk applications.

<u>Table 2</u>: R-T measurements in air and maximal possible signals from the info-layers S_1, S_2 for the corresponding optical constants n and k

Red-laser results:

batch	reflectance at 633nm	transmittance at 633nm	thickness measured	calculated optimal thickness	signal of 1st info-layer	signal of 2nd info-layer
	R %	T %	dm nm	dopt nm	S1 %	S2 %
6	62.2	23.2	35.1	15.2	25	25
12	47.8	41.8	51.3	48	28	28
42	63.4	28.1	39.1	18.5	29	29
45	46.3	51.5	57.4	56.3	26.2	40.8

Blue-laser results:

batch	reflectance at 450nm	transmittance at 450nm	thickness measured	calculated optimal thickness	signal of 1st info-layer	signal of 2nd info-layer
	R	T	dm	dopt	S1	S2
	%	%	nm	nm	%	%
42	38	36.4	39.1	9.2	21	21
45	28	40.5	57.4	34	25	25

Table 3: Stoichiometry of the batches benchmarking the limits ($\pm$ 10%) of useful refractive indices for DVDs

batch	Si	O	N	C	H	n633nm	n450nm
	%	%	%	%	%		
6	78	5	11	2	4	4.19	
12	58.6	2	36.4	2	1	3.02	
42	70.4	7.8	0	8.7	13.1	3.97	4.35
45	49.4	4.2	0	23.8	22.6	2.81	3.04

Thus, as a band for the index of refraction, according to the present invention, we finally propose:

$2.59 \leq n_1 \leq 4.6$, thereby especially $2.8 \leq n_1 \leq 3.2$.

For the index of refraction k, we finally propose the following values:

$k_{300nm} \leq 3.0$ and/or $k_{350nm} \leq 2.7$ and/or

$k_{600-700nm} \leq 0.5$, especially ≤ 0.1, and/or $k_{450-500nm} \leq 1$.

Resuming the present invention, the following objects are resolved:

- low cost manufacturing due to the fact that, exploiting the proposed stoichiometries, very thin layers may be used which drastically reduces manufacturing time;

- matching of multiple reflected beams;

- possibility to adjust signal levels to player capabilities;

- possibility to adjust the signal levels reached to the thickness distribution performance realizable with a specific coating chamber;

- improved adherence on chamber walls and masks for metallic-like layers to reduce flaking-off problems;

- simpler process control in that it is possible to work near the metallic deposition mode. The closer one can work in a reactive process to the metallic mode, the smaller is the danger to abruptly and uncontrollably jump into reactive mode;

- the use of nitrogen instead of propane or methane additionally reduces security measures.

- realization of 25% signals from two information carrying interfaces even with a blue laser at 450nm.